AN APPROACH TO ATE CALIBRATION
VIA PERFORMANCE VERIFICATION
AT THE SYSTEM INTERFACE

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ABSTRACT

A method of verifying the performance of automatic test equipment (ATE) in its normal operating environment and configuration is presented as the best approach to achieving an overall system calibration. The method consists of the transport of well-characterized signal sources to the ATE station and the application of these electrical stimuli directly to a well-defined electrical interface on the test station. Data is presented on typical accuracies that have been obtained on limited parameters and ranges during the testing process, using calibrated commercial equipment.

INTRODUCTION

Several approaches have been used to assure that ATE systems perform properly. The traditional approach is the calibration of each "drawer" or instrument of the system. Typically, instruments such as a digital voltmeters, precision voltage or waveform sources, and frequency counters, are removed from the ATE station and sent to a calibration laboratory where their performance is evaluated and any necessary calibration adjustments are made. Such an approach has several shortcomings. For example, the test system often cannot be used during the time the instruments are removed for calibration unless replacements can be found. A more serious deficiency of this approach, from a metrology point of view, is the fact that instruments are not characterized in the same environment as they are used. For example, the accuracy of a digital voltmeter may exhibit sensitivity to temperature changes. Its normal operating temperature range in the ATE system may be quite different than that encountered in the calibration laboratory. In addition, interferences, such as high frequency signals produced by other instrumentation and computers in the ATE system may degrade the performance of such precision measurement equipment. These effects are usually not present when the performance of the measurement equipment is evaluated in the calibration laboratory. A further shortcoming of the practice of removal, calibration, and replacement of measurement equipment is that such procedures result in a calibration that does not account for losses and offsets in the signal path between the interface connector, where the unit under test UUT is connected, and the instrument terminals, where the instrument was calibrated. Since signals from the UUT are typically switched through relays and have relatively long path lengths, signal losses and offsets may affect the measurement accuracy, especially for low-level signals. In view of the shortcomings listed above, the user of ATE which has had instruments removed and calibrated outside the ATE system itself may have greater confidence in the equipment performance than is warranted.

Another calibration approach employed with ATE systems in order to increase the confidence in the resulting measurements is the use of various types of built-in test or self-testing schemes. If properly implemented, such schemes may be valuable towards assuring that measurements made by an ATE system are consistent. However, such techniques alone cannot perform a calibration function to determine the difference between values of physical quantities, such as voltage and frequency, measured by the ATE system and those measured quantities that have traceability to national standards. Measurements have traceability to a designated set of standards if and only if scientifically rigorous evidence is produced on a continuing basis to show that the measurement process is producing measurement results for which the total measurement uncertainty relative to national or other designated standards is quantified [1].

To assure verification of the performance of test equipment, and achieve meaningful traceability, well-characterized standards must be applied to the ATE station while it is operating in its normal environment. An example of such an "in-situ" station calibration is the Portable Automatic Test Equipment Calibration Concept (PATEC) used by the Air Force Guidance and Metrology Center. The PATEC concept consists of verifying the performance and calibrating certain critical or "core" instruments used by the ATE system using portable programmable calibrators connected via the system interface. After such direct calibration, the remainder of the instrumentation contained in the station are then calibrated by using the core instruments as standards, together with "wrap around" interface adapters. The Navy implements a similar concept using the Modularly Equipped and Configured Calibrators and Analyzers (MECCA). Both of these programs utilize portable calibration systems that assure the performance of ATE on site via a system calibration.

THE USE OF TRANSPORT STANDARDS

The National Bureau of Standards (NBS) has had a program, in cooperation with the Department of Defense (DoD) to determine the feasibility of using transport standards to verify the performance and calibration of ATE systems [2]. The approach employs the use of portable transport standards with sufficient accuracy and long-term stability to properly characterize the ATE station under investigation. It was essential that these transport standards were sufficiently versatile so as to permit the application of a range of well-calibrated stimuli directly to the UUT interface connector. A realistic evaluation of the accuracy of the ATE system could then be made when the system was operating in essentially the same conditions as when testing a UUT.

Portable transport standards offer an advantage over alternative methods of characterizing an ATE station since the effects of losses and offsets occuring in the cabling and switching networks can be also properly characterized. In addition, it is desirable to be able to program the transport standards by means of a computer or instrument controller since statistically meaningful tests require that lengthy sequences of stimuli be applied to the ATE system under test. For example, to adequately characterize ac voltage measurements made by an ATE system, many combinations of voltage amplitudes and frequencies must be applied. Portable transport standards, in conjunction with portable "desk-top" controllers, offer a powerful way to generate such sequences, with the flexibility of making possible program changes on site.

IMPLEMENTATION OF THE TRANSPORT STANDARDS FOR AC, DC, PHASE, AND PULSE PARAMETERS

Based on a knowledge of the key measurement capabilities of an ATE system to be characterized, the parameters and ranges of the required stimuli can be selected. For example, in this particular project ac and dc voltages, electrical phase angle, and pulse duration were the quantities used to characterize one particular "third-generation" ATE system initially studied by NBS. DC voltages from +/- 100 mV to +/- 195 V, and ac voltages from 300 mV to 140 V (rms) at various frequencies from 50 Hz to 10 MHz were applied to the ATE system at the UUT interface connector in order to investigate its dc and ac measurement performance. Additionally, it was desired to verify the performance of the ATE station in measuring pulse duration over a range of 50 nS to 1000 ns.

Two transport packages consisting of test equipment were assembled; one for the dc and low-frequency ac voltage source, and the second for a pulse voltage source. The dc and low-frquency ac voltage source package contained a commercial meter calibrator, a digital voltmeter, and a desk-top computer/controller. The pulse source package contained a high resolution time synthesizer for generating pulses of precise time duration, and a pulse generator that was used to generate the output repetition rate of the pulses. In addition, an NBS Phase Angle Calibration Standard was used as a source of phase angle signals [3]. The NBS Phase Angle Calibration Standard produces a pair of digitally synthesized sine waves. All parameters, with the exception of the pulse repetition rate, were capable of being controlled by the computer/controller via an IEEE-488 bus. Thus, sequences of various voltages or pulse widths could be applied to the ATE system with a minimum of operator intervention.

Prior to applying these sources to an ATE system, the transport packages were carefully characterized to measure their accuracy, their stability with time, and the effects of temperature, line voltage, and other environmental factors that may affect their performance. In all cases, the characterization of the transport standards package was performed at the termination of the cable and adapters that were necessary to interconnect the standards with the ATE system under investigation. Furthermore, the input impedance of the ATE system was simulated with resistance-capacitance networks at the interconnection interface. Thus, the electrical environment during the characterization tests performed on the transport standards approximated that encountered during the connection of the transport standards to the ATE system.

For example, the output of the dc transport source was intercompared periodically with the U.S. Legal Volt maintained by NBS. Over a period of five months, the dc source exhibited a 3 sigma uncertainty of less than 0.004 percent over a voltage range of +/-0.1 to +/-200 V dc. Likewise, over a three month period, the pulse source exhibited changes in pulse duration of less than +/-0.6 percent over the range of 50 to 1000 ns.

The voltage of the ac output from the source was measured as a function of rms amplitude and frequency by means of a thermal voltage converter. The ac and dc voltages of the source were available at the same output terminals by programming the source over the IEEE-488 bus. The output of the thermal converter was measured by the digital voltmeter, also controlled by the bus. In this manner, full control was exercised over the generation and application of ac and dc voltages to the converter and over the recording of the resultant thermocouple emf voltages. A multiplier (current scaling resistor), inserted between the source and the thermoelement allowed the thermal converter to be used over a voltage range of 2 to 600 V ac (rms).

The observed 3 sigma uncertainty in the voltage of the ac source over the frequency range of 50 Hz to 50 kHz was less than +/-0.01 percent during a three month period. The combined effects of temperature and line voltage changes along with additional uncertainties contributed by the thermal converters, voltmeter non-linearities, and effects due to movement of the source from the calibration laboratory at NBS to the remote ATE site gave conservative estimates of total uncertainties of +/-0.02 percent and +/-0.12 percent for dc and ac voltages, respectively.

AC voltages at frequencies between 50 kHz and 10 MHz are more difficult to measure accurately than those at lower frequencies. At the higher frequencies, small inductances and capacitances associated with the connection of the calibration source to the ATE system become important. If not properly accounted for, the losses in the cable between the wideband output of the source and the interface of the ATE system introduce a source of systematic uncertainty. To connect the source to the ATE system, a 1.5-m cable is required. Typically, this additional cable length provides an attenuation of the signal of approximately 0.6 percent at 10 MHz. Thus, all measurements were made using a 1.5 m length of RG-58/U cable connected to the wideband output unless otherwise specified.

The ac voltage output at the interface adapter pins, as a function of frequency, was determined by the use of a thermal voltage converter which has a specified input impedance of 50 ohms (+/- 0.3 percent) and a voltage range of approximately 0.2 to 0.45 V ac (rms). To measure voltages in excess of 0.45 V ac, a set of two precision 50-ohm coaxial attenuators was used that had power attenuations of 6 and 10 dB respectively. By means of the attenuators, either individually or in series, the voltage measurement range could be extended to 2.8 V ac. The overall uncertainty of the output voltage of the wideband source at the interface adapter pins was calculated to be +/-0.7 percent. This value was deemed to be more than adequate for verifying the performance of an ATE station with a +/- 3 percent accuracy specification.

APPLICATION OF TRANSPORT STANDARDS TO AN ATE SYSTEM

The transport standards were applied to several third-generation ATE systems used by DoD. Measurement programs were written in ATLAS to permit the ATE station to measure dc voltages, low frequency ac voltages in the frequency range of 50 Hz to 50 kHz, and high frequency ac voltages in the range of 50 kHz to 10 MHz. Additional programs measured pulse duration and phase angle. The transport standards were interconnected to the ATE system by means of the cables and the interface adapter that had been used in the characterization of the standards. This overall package permitted the application of the ac and dc voltages, pulses, and phase angles to the ATE system under the same conditions in which they were calibrated. In addition, a means was provided for the ATE station to generate a "test complete" pulse to the controller. The controller then instructed the transport standards to provide the next stimuli in a preprogrammed sequence. The measurements from the ATE station were printed and recorded on the system disk file. In this manner, an extensive set of measurement data could be obtained to analyze the errors of the ATE system being characterized since all the data was in "machine compatible" form.

CONCLUSION

The use of accurate transport standards has been demonstrated to be a useful concept for the characterization and calibration of ATE systems. In order to meaningfully characterize the performance of an ATE system, the signals must be accurately determined at a defined measurement interface over the range of environmental conditions that typically would be encountered.

REFERENCES

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